Wind Input, Surface Dissipation and Directional Properties in Shoaling Waves

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LONG-TERM GOAL

We wish to improve our understanding of the physics and interactions which govern the spatial and temporal evolution of surface waves in finite depth water.

SCIENTIFIC OBJECTIVES

1) To measure the direct wind forcing of waves as they advance into shallow water.
2) To measure the evolution of the wavenumber spectrum as the waves shoal.
3) To estimate the kinetic energy dissipation in the surface waters.
4) To determine the dependence of the energy and momentum input into shoaling waves on the wavenumber spectrum and the wind.
5) To determine the dependence of wave dissipation on the wavenumber spectrum and the rate of shoaling.
6) To determine the directional response of the wavenumber spectrum on surface current shears and variable bottom bathymetry.

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APPROACH

An extensive field program is planned to study the spectral balance of shoaling ocean waves. A triangular array of air-sea interaction spar (ASIS) buoys will be used to acquire observations of meteorological variables (wind stress and stability), directional wave spectra, and mechanical energy dissipation in the water. In addition, measurements of these quantities as a function of fetch, as well as direct measurements of the wind input to the waves, will be obtained from a small SWATH ship. These measurements will be used to estimate source terms for wind input and wave dissipation. The measured spectral evolution of the wave field will be compared to calculations based on the action balance equation and incorporating the measured source terms. An HF Doppler radar will measure surface vector currents over the same domain as the triangular spar buoy array. Combining the current measurements with the spectral wave data will be used to estimate the intensity of wave-current interactions and high-resolution bathymetric data will be used to study the variability of wave transformation due to small-scale variations in the bottom topography.

Prior to the full scale field experiment (Fall 1999) all our systems will be field tested. The SWATH ship will be equipped with a boom extending orthogonally out from the starboard side and a mast positioned at the bow. The boom will carry a laser gauge array to measure the surface elevation. At the end of the boom is a retractable spar which carries sets of pitot tubes, Elliot pressure probes and hot film anemometers at four different vertical levels above the water surface. Additional sets (3) will be placed on rigid poles to measure the influence of flow distortion around the bow.

The three ASIS buoys will be deployed in a joint calibration/validation experiment for passive microwave radiometry (WindSAT) and scatterometry (QuickSAT). The month-long deployment will take place in the northeastern part of the Gulf of Mexico. The buoys will be arranged in a equilateral triangle with a side length of about 10 km. The center of the triangle will contain a discus buoy from NDBC (42036). The instrumentation configuration and the data recording system will be field tested during this experimental phase.

WORK COMPLETED

1) The modified version of the ASIS buoy was deployed during a month long experiment called FETCH, a European-funded ERS-2 validation experiment, in the northwestern part of the Mediterranean Sea in March/April 1998.
2) Materials and system components have been acquired to assemble two more complete (spar and tether buoy) ASIS systems. The results of the recent FETCH experiment were used to make final changes to the buoy design. Design modifications on both the analog and digital recording systems were completed and are currently being assembled for use in the Gulf of Mexico field test.
3) A suite of instrumentation acquired under a DURIP project was tested and integrated with the data recording systems for the ASIS buoys. Also all other sensors have been assembled and built.
4) In October 1998 a week long field test was conducted in Halifax harbor and in the open ocean east of Halifax with the SWATH in its configuration (side boom and bow mast) for the Shoaling Waves Experiment at Duck, NC.
5) As part of the FETCH experiment and SWATH field test several calibration and data processing software were developed for analyzing the data.
6) In early October 1998 a final workshop was conducted with all SHOWEX investigators at the Field

Research Facility (FRF) at Duck, NC.

7) The SHOWEX web site is continued and further developed to disseminate experimental plans and time tables and coordinate measurement strategies. The web site has been moved to http://cheyenne.rsmas.miami.edu/duck99 .

RESULTS

A recent deployment in the Mediterranean Sea (March/April 1998) demonstrated the buoy's ability to obtain high quality measurements of waves and air-sea fluxes in winds up to 20 m/s and waves in excess of 3 m. Figure 1 shows the relationship between wind speed and drag coefficient, C_{d10}, and the deviation of the wind stress angle from the mean wind direction as measured during FETCH. It is noteworthy to see that the stress measurements exhibit smaller scatter with increasing wind speed. While the trend in the drag coefficient data follows the most recent bulk formula by Smith (1980) and Yelland and Taylor (1996), there remains considerable variations in C_{d10} which suggest far more complex sea conditions than those associated with pure wind seas (Drennan *et al*. 1998). Note especially for low winds the disagreement with the bulk formula can be significant. Similarly, the lower panel presents data which is consistent with the notion that the deviation between wind stress angle and mean wind direction approaches zero for high wind speeds. At low winds speeds, the influence of swell is much more pronounced and causes the wind stress angle to differ considerably from the wind direction.

Figure 2 displays a comparison of the significant wave height, H_s, computed from the wave gauge array on the ASIS with measurements obtained from a Datawell directional waverider which was colocated (within 2 km) from the ASIS buoy during FETCH. The agreement is excellent as is indicated by a bias of only 3.2 cm and rms difference of 7.3 cm. The correlation coefficient for this data set is 0.993.

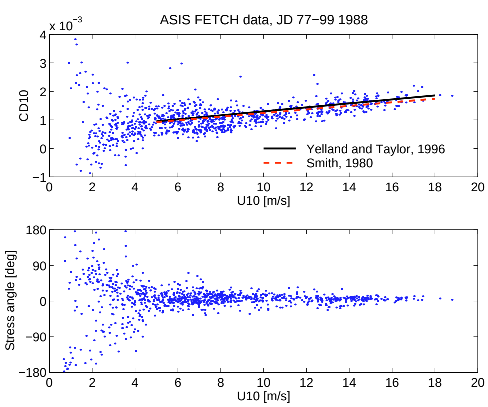

Figure 1: Wind stress data obtained by the ASIS buoys during the FETCH experiment in the Mediterranean Sea. The upper panel shows wind speed against drag coefficient. The lower panel shows wind speed against the deviation of the stress angle from the mean wind direction.

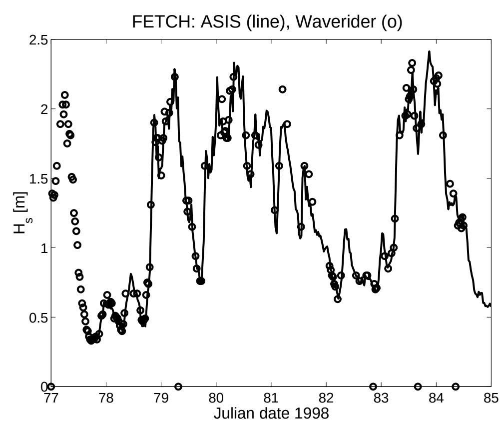

Figure 2: Comparison of ASIS buoy derived significant wave height with H_s values from colocated directional waverider from the Finnish Institute of Marine Research.

An extensive field test was conducted with the SWATH ship inside and outside of Halifax harbor. The SWATH ship was fully configured with a side boom extending orthogonally of the starboard side near the bow. A meteorological mast was also positioned at the center of the bow. Figure 3 shows the SWATH ship *Frederick Creed* during the sea trials inside Bedford Basin.

The boom was instrumented with five laser ranging sensors to measure surface elevation. The outer radius of the triangle is 75 cm and the radius of the inner triangle formed at the forward most laser is 10 cm. Also at the seaward end of the boom was a retractable spar which was instrumented with four sets of pitot tubes, Elliot pressure probes and hot film anemometers. The vertical spacing between the sets of sensors is 50 cm. In addition, three vertical poles were placed along the boom with pairs of pitot tubes and Elliot pressure probes to measure the influence of flow distortion around the starboard hull. An R.M. Young wind anemometer vane will provide wind speed and direction observations near outer edge of the boom. Figure 4 shows a close-up view of the boom configuration on the SWATH ship.

Figure 3: SWATH ship *Frederick Creed* fully configured for the Shoaling Waves Experiment during sea trials in Bedford Basin, Nova Scotia.

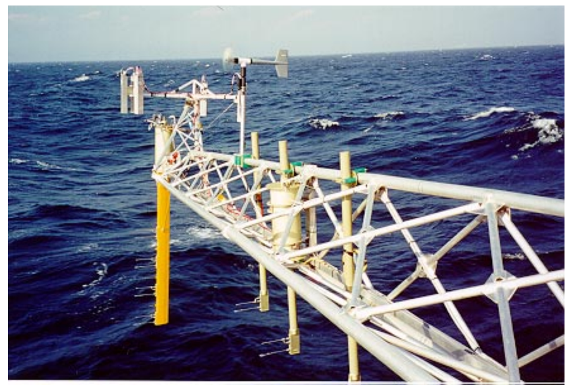

Figure 4: A close-up view of the SWATH ship boom showing the laser ranging array and the retractable spar with the sets of Elliot pressure probes, pitot tubes and hot film anemometers.

At the center of the bow was a meteorological mast equipped with five levels of cup anemometers, two sonic anemometers and an R.M. Young wind anemometer (see Figure 3). The numerous levels of anemometers will be used for direct wind stress measurements and to establish the influence of flow distortion induced by the ship's superstructure. Air temperature sensors will also be placed on the mast as well as a humidity sensor. Two radiation sensors (incoming and net solar) will be mounted to the roof of the bridge.

Figures 5 and 6 show preliminary results from the laser gauge array. Note the quality of the timeseries signals and the one-dimensional energy spectrum.

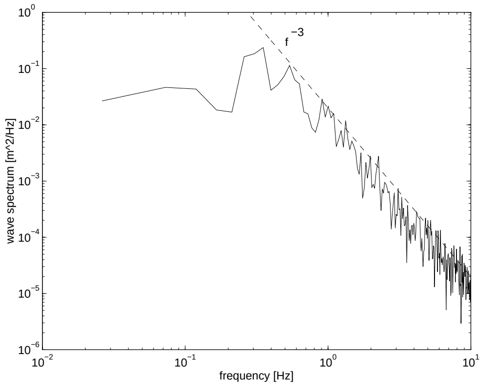

Figure 5: A time series of elevation of the surface measured by two laser altimeters : (solid) forward altimeter; (dashed) the rear outer altimeter, being 1.125 m to the rear and 0.65 m to the starboard. Elevation is relative to the end of the boom as the ships's motion has not been removed.

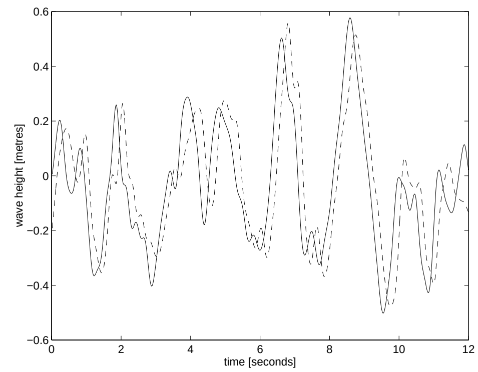

Figure 6: The spectrum of relative wave elevation as measured by a laser altimeter on the SWATH ship travelling at 7 m/s into the waves. The spectral fall-off shown (f^{-3}) corresponds to the expected k^{-3} dependence of the spatial spectrum observed along the ship's track in a wind-generated sea.

IMPACT/APPLICATION

None yet.

TRANSITIONS

None yet.

RELATED PROJECTS

None yet.

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